Lasers in Surgery and Medicine 22:275–280 (1998)

Comparative Study of Surface Displacement in Discs Following Chemonucleolysis and Lasernucleotomy

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Background and Objective: **Dynamic changes of the dorsolateral protrusion site have been postulated to play an important role in the therapeutic effect of lasernucleotomy and chemonucleolysis. Basic biomechanical effects of the anulus after lasernucleotomy and chemonucleolysis are investigated.**
Study Design/Materials and Methods: **This study evaluates the in vitro bulging of lumbar discs comparing lasernucleotomy and chemonucleolysis. The horizontal displacement at the ventral and dorsolateral surface of 20 cadaver discs were tested by application of a continuously increasing axial deformation before and after therapy. The increase in horizontal displacement due to this longitudinal deformation was measured.**
Results: **Bulging was significantly lower at the puncture site of the chemonucleolysis needle as well as at that of the laser trocar. Significantly reduced bulging of the anulus was observed after chemonucleolysis. Slightly increased bulging was observed after lasernucleotomy in the total posterior region. There was a tendency to decreased stiffness after chemonucleolysis and a significantly decreased stiffness after lasernucleotomy.**
Conclusions: **The in vitro effect of lasernucleotomy seems to be based on reduction of the stiffness by distributing the load all over the anulus, whereas chemonucleolysis reduces bulging. Lasers Surg. Med. 22:275–280, 1998.**

Key words: **pressure measurement; disc protrusion; percutaneous disc surgery; disc deformation**

INTRODUCTION: TREATING PROLAPSED DISCS

Percutaneous treatment of disc protrusions was diversified by introduction of new methods. Besides the semiinvasive methods of treatment of prolapsed discs, chemonucleolysis and percutaneous nucleotomy [1–3], lasernucleotomy is now established as a third method [4–12]. Up to now, most retrospective and prospective clinical investigations refer to chemonucleolysis as a standard procedure [1,13–16]. Therefore, novel methods are compared to chemonucleolysis [17]. In a randomized multicenter study, automated percutaneous discectomy, strongly propagated during the 1980s, yielded less satisfying results than chemonucleolysis [18]. In contrast, lasernucleotomy, the most recent method, showed satisfying results in several studies [5,6,19]. However, there are no reports in the literature on experimental comparative studies. Experimental studies measuring in-

Contract grant sponsor: Scientific Board of the Lord Mayor of Vienna.

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Accepted 2 April 1997

tradiscal pressure in chemonucleolysis as well as in lasernucleotomy showed a decrease in intradiscal pressure for both methods [6,20–22]. Up to now, the biomechanical changes of the outer posterior anulus have not been investigated in a comparative study. The posterolateral deviation by disc protrusion is responsible for the compression of the adjacent dorsal neurogenic structures [3,23]. Therefore, we investigated the outer deviation of the disc before and after lasernucleotomy and chemonucleolysis, respectively, and compared the effects of both methods on the dorsal anulus area.

MATERIALS AND METHODS

Disc Specimens

Twenty segments of cadaver discs from human lumbar spines were prepared for both methods. Segments consisting of two vertebral bodies and one disc each were resected and investigated within 48 hours after resection. The specimens were stored at −4°C and warmed up toward room temperature prior to investigation. The segments were dissected from the adjacent soft tissue, longitudinal ligament, processus transversus, processus spinosus, and pedicle. The vertebral bodies were cut parallel to the horizontal plane of the intervertebral disc so that the axial force could be distributed perpendicularly over the disc. For reproducibility of the investigations, we chose only macroscopically unchanged discs. All discs with spondylosis, spondylarthrosis, and small intervertebral space (<0.6 mm) were excluded. Intact discs were determined by two repeated load cycles before treatment. Discs without reproducible pretreatment measurements were classified as pathologic discs and excluded from the study. All discs in the study showed comparable values before treatment. Of these 20 lumbar segments, we treated 10 discs each by lasernucleotomy and by chemonucleolysis, respectively.

Laser

For this series of experiments, we used a 2.12 μm Holmium-YAG laser (Coherent/USA) with a pulse duration of 250 μsec. For nucleus vaporisation we used a 360 μm fiber (Clarius/USA) with a trokar-permitting ablation as well as suction. Ablation was performed under continuous rinsing with saline solution and suction at a flow of 10 ml per minute. In all cases the laser fiber was positioned dorsolaterally on the side of sensor 3. Energy was increased stepwise by 1 kJ and was interrupted for 30 seconds after each step (range 1–10 kJ). Ablation was performed at an energy of 1.4 J and a frequency of 10 Hz up to 10 kJ total energy, in accordance with the clinical instructions for lasernucleotomy [10–12].

Chemonucleolysis

Chymopapain (Chymodiactin®, Boots) was diluted in 2 ml aqua bidest. In our experimental setup, we used 4,000 units chymopapain per nucleus. To ensure a constant effect of chymopapain, the measurements were performed routinely starting immediately after and up to 2 hours after injection, according to the instant effects described in prior publications [15,24].

Experimental Setup

The biomechanical testing machine controlling the axial displacement consisted of an axial fixing device for the vertebral segment permitting the application of a continuously increasing deformation force. Axial shift was introduced (0.5 mm/turn) and the axial forces were measured in Newton (N) by an integrative measurement device (Technical University of Vienna). Three sensors were positioned ventrally and on both sides dorsolaterally of the disc. The displacement produced by the lateral surface deformation of the anulus was measured by the sensors each connected to a candelabra beam supplied with a strain gauge half bridge (Fig. 1). The measurement device for the lateral deformation was connected to an elastic candelabra beam, and dislocation of the tip of the strips could be measured with an accuracy of ±0.01 mm. The data measured were recorded by a data logger (Schlumberger, Vienna). The measurement device could be fixed by a magnetic rack at a variable position and height according to the dimensions of the test specimens. The test specimens were fixed with claw plates and bone cement (Sulfix®) perpendicular to the axis to avoid the occurrence of horizontal shear forces.

Measurement

The experiment was performed stepwise under deformation control up to a corresponding total load of 400 Newton (average velocity: 2.5 N/sec). Before the treatment two load cycles were done to ensure reproducible data. Bulging of the disc was measured as mm value (Fig. 2). We compared the horizontal displacement due to analogous load cycles before and after therapy, calculated in mm lateral per mm axial decrease of the longitudinal disc deformation. Elasticity, the re-

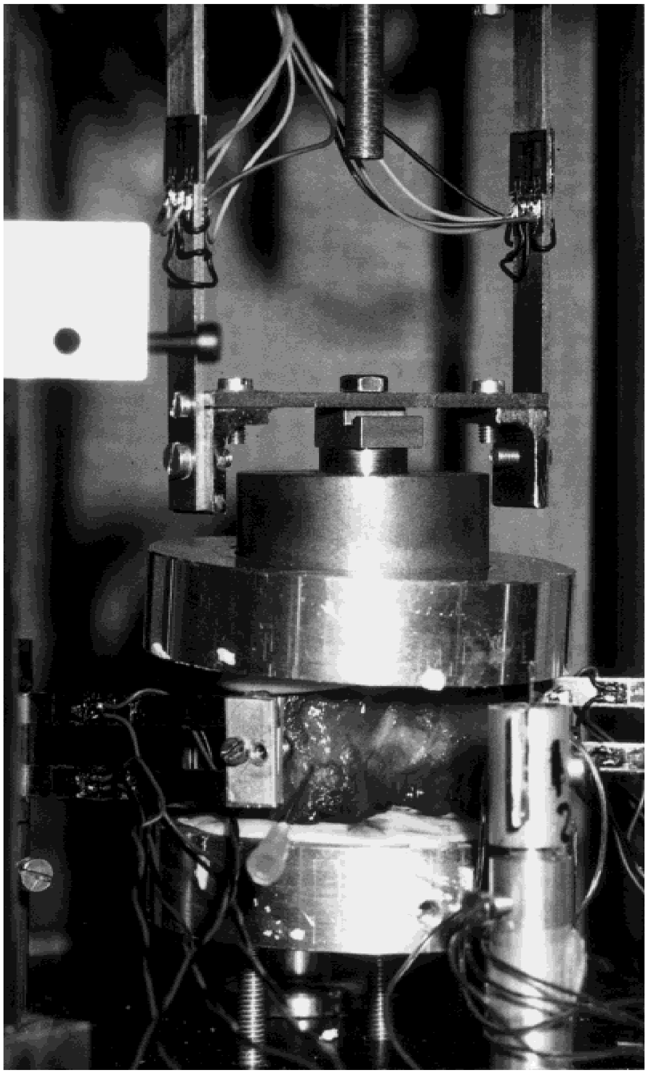

Fig. 1. Measurement device with candelabra beam in dorsolateral position of the disc. Vertebral segment fixed with claw plates and bone cement.

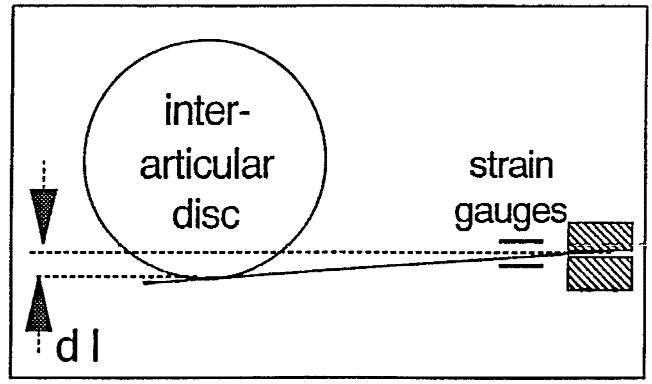

Fig. 2. Measurement of disc bulging with strain gauge.

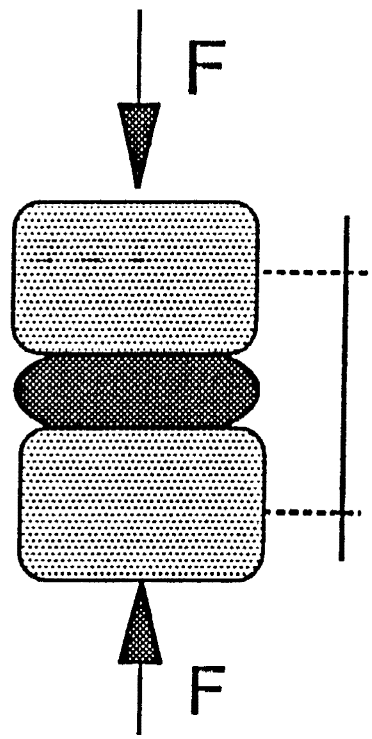

Fig. 3. Measurement of stiffness to a given axial deformation.

ciprocal value of stiffness, was measured in Newton per μm decrease (Fig. 3).

Statistics

Multivariant analysis using statistical methods to analyze the basic effect was performed. Statistical analysis was performed using Student's t-test and significance was assumed at *P* values <0.5.

RESULTS

Preoperative Bulging

The preoperative measurements of the external anulus bulging exhibited no statistical difference between the starting values before chemonucleolysis and lasernucleotomy. After setting the chemonucleolysis needle, an axial load of up to 400 Newton resulted in a bulging of 0.52 mm ± 0.32 mm, 0.49 mm ± 0.29 mm, and 0.28 mm ± 0.11 mm as measured by the sensors 1, 2, and 3, respectively (Table 1). Statistical evaluation showed a significantly lower value ($P < 0.05$) for the measurement of sensor 3 in immediate vicinity of the chemonucleolysis needle. Equal axial load after setting of the laser trocar resulted in a bulging of 0.34 mm ± 0.08 mm, 0.29 mm ± 0.06 mm and 0.10 mm ± 0.08 mm as measured by the sensors 1, 2,

TABLE 1. Distribution of Bulging (in mm) Comparing Chemonucleolysis and Lasernucleotomy

	Preop.	*P* value	Postop
Sensor 1			
Laser	0.25 ± 0.1	n.s.[a]	0.28 ± 0.18
P value	n.s.[a]		n.s.[a]
Chemonucl.	0.28 ± 0.24	n.s.[a]	0.46 ± 0.42
Sensor 2			
Laser	0.22 ± 0.12	n.s.[a]	0.88 ± 0.38
P value	n.s.[a]		<0.05
Chemonucl.	0.21 ± 0.21	n.s.[a]	0.14 ± 0.08
Sensor 3			
Laser	0.12 ± 0.1	<0.05	0.22 ± 0.14
P value	n.s.[a]		0.05
Chemonucl.	0.21 ± 0.13	<0.05	0.12 ± 0.05

[a]n.s. = not significant.

TABLE 2. Comparison of Preoperative and Postoperative Ratio of Lateral Elasticity (per definition the reciprocal value of the stiffness) Against Axial Loading

	Preop. (N/μm)	*P* value	Postop.
Laser	0.44 ± 0.1	<0.01	0.35 ± 0.08
P value	n.s.[a]		n.s.[a]
Chemonucl.	0.45 ± 0.38	n.s.[a]	0.39 ± 0.36

[a]n.s. = not significant

and 3, respectively. In this case, too, there was a significant decrease ($P < 0.01$) in the vicinity of the trocar, as measured by sensor 3. Preoperative comparison of both methods showed a significantly decreased bulging after setting of the laser trocar (0.10 mm ± 0.08 mm vs. 0.28 mm ± 0.11 mm, $P < 0.01$). There was no significant difference in the stiffness of the disc (μm/N) after puncture with the different instruments (Laser nucl. 0.17 mm ± 0.04 mm vs. Chemonucl. 0.18 mm ± 0.15 mm).

Postoperative Bulging

After chemonucleolysis we found a decreased bulging within the dorsal areas of sensors 2 and 3 due to axial loading. However, the same measurements after laser therapy showed an equally distributed bulging in the ventral and dorsal sections. Comparison between pre- and postoperative values after chemonucleolysis exhibited a significantly decreased bulging at sensor 3 and an obvious, but not significant reduction in bulging at sensor 2 due to axial loading. After laser therapy we found a significantly increased bulging at sensor 3 and an insignificant increase at sensor 2 after axial loading (Table 1). In a direct postoperative comparison with chemonucleolysis, laser treatment exhibited significantly increased bulging. Whereas the stiffness of the disc decreased significantly with laser treatment, there was only a slight tendency toward decreased stiffness of the disc in chemonucleolysis (Table 2).

DISCUSSION

Chemonucleolysis with chymopapain is disputed because of its side effects, as anaphylaxis, neurologic complications up to transverse myelitis and back spasm [25,26], but represents an established method with clinical efficiency evidenced in double-blind studies [1,14,16]. Percutaneous lasernucleotomy is regarded as the latest semiinvasive method of treatment with encouraging results [6,8,11,12,19]. However, standardized comparative studies are still missing.

Intravital biomechanical investigations reported a definite reduction in intradiscal pressure brought about by injection of chymopapain [27]. Wakano et al. [22] found a decrease in stiffness of the disc 3 weeks postchemonucleolysis. Choy et al. [20] also reported a decrease in intradiscal pressure in laser-treated cadaver discs. They support the hypothesis that a sudden decrease in intradiscal pressure induced by laser evaporisation of the nucleus might cause a retraction of the prolaps and thereby a relief of the nerve root [6]. Therefore, the present study was designed to compare for the first time the basic biomechanical effect of chemonucleolysis and lasernucleotomy on the dorsal outer circumference of the disc.

Proceeding on the assumption that pressure relief of the dural sack and the nerve root, respectively, is one of the determining factors for the success of a semiinvasive method of disc prolaps treatment [6,13,25,26,28,29], the relevant factor is not the intradiscal pressure, but the displacement of the disc at the dorsal circumference under increasing axial load. The publications by Hoppenfield [30] and Kambim and Brager [31] postulating an effect of fenestration of the anulus by the nucleotomy instruments caused us to check this effect by our experimental setup. Therefore, we measured the effects of the positioning of the nucleotomy instruments exerted on the circumferential displacement of the disc. Confirming this hypothesis, our results show a significantly lower bulging at the area of insertion of instruments. This phenomenon might be explained by a stabilizing effect by the setting of the instruments. It was most pronounced at sensor 3 in immediate vicinity of the setting instrument and de-

creased with increasing distance from it. Thus the highest bulging values were measured at the most distant sensor 1. The considerably large diameter of the laser trocar also might result in a higher mechanical stabilization of the anulus as compared to the thinner chemonucleolysis needle (2.0 mm diameter of the laser trocar vs. 1.0 mm diameter of the chemonucleolysis needle). However, in a previous group consisting of five discs, the measurement after removing either the trocar or the needle without treatment showed practically no differences (due to a reachable accuracy) to the measurement before setting the instruments. Posttherapeutic measurements mainly indicate a decreased dorsal bulging after chemonucleolysis and an increased dorsal bulging after lasernucleotomy.

With our experimental setup, we were able to show that—in healthy discs at least—chemonucleolysis and lasernucleotomy exert different effects on the circumference of the anulus. The results of our study demonstrate that intradiscal injection of chymopapain significantly decreases bulging. Other authors also report significantly reduced intradiscal pressure upon application of chymopapain [27]. Furthermore, our investigation shows that reduction of intradiscal pressure after chemonucleolysis is associated with an only minor decrease in stiffness of the disc. Despite the enzymatic processes, the nucleus preserved a residual axial stiffness and was able to absorb a certain amount of axial pressure. The essential effect of action was a decreased intradiscal pressure with a maintained loading capacity of the nucleus. The therapeutic effect of lasernucleotomy seemed to be basically different from that of chemonucleolysis. The vaporisation of the nucleus resulted in a significantly lower axial stiffness of the disc. Following lasernucleotomy, bulging was found to be significantly increased mainly within the dorsal region and axial load caused the dorsal deformation. The postulated decompressive effect of lasernucleotomy on diseased discs could not be confirmed by our experimental setup, because for reasons of availability and reproducibility, only healthy discs could be used. However, after laser therapy of prolapsed discs top loads within the prolapsed area may be distributed all over the circumference of the anulus, thereby avoiding or reducing top loads within this restricted area. The results of this study were obtained under in vitro conditions. In our opinion these results might serve as a biomechanical basis for principle action after lasernucleotomy and chemonucleolysis on the outer circumference of the disc. Nevertheless, caution is required in extrapolating results obtained under laboratory conditions to the clinical setting. Therefore, further studies will be necessary to reveal a possible significance of these fundamental findings for clinical use.

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